Is it Time for a "Sun Shot"?

$1/Watt Workshop
Washington, D.C.
10 August 2010

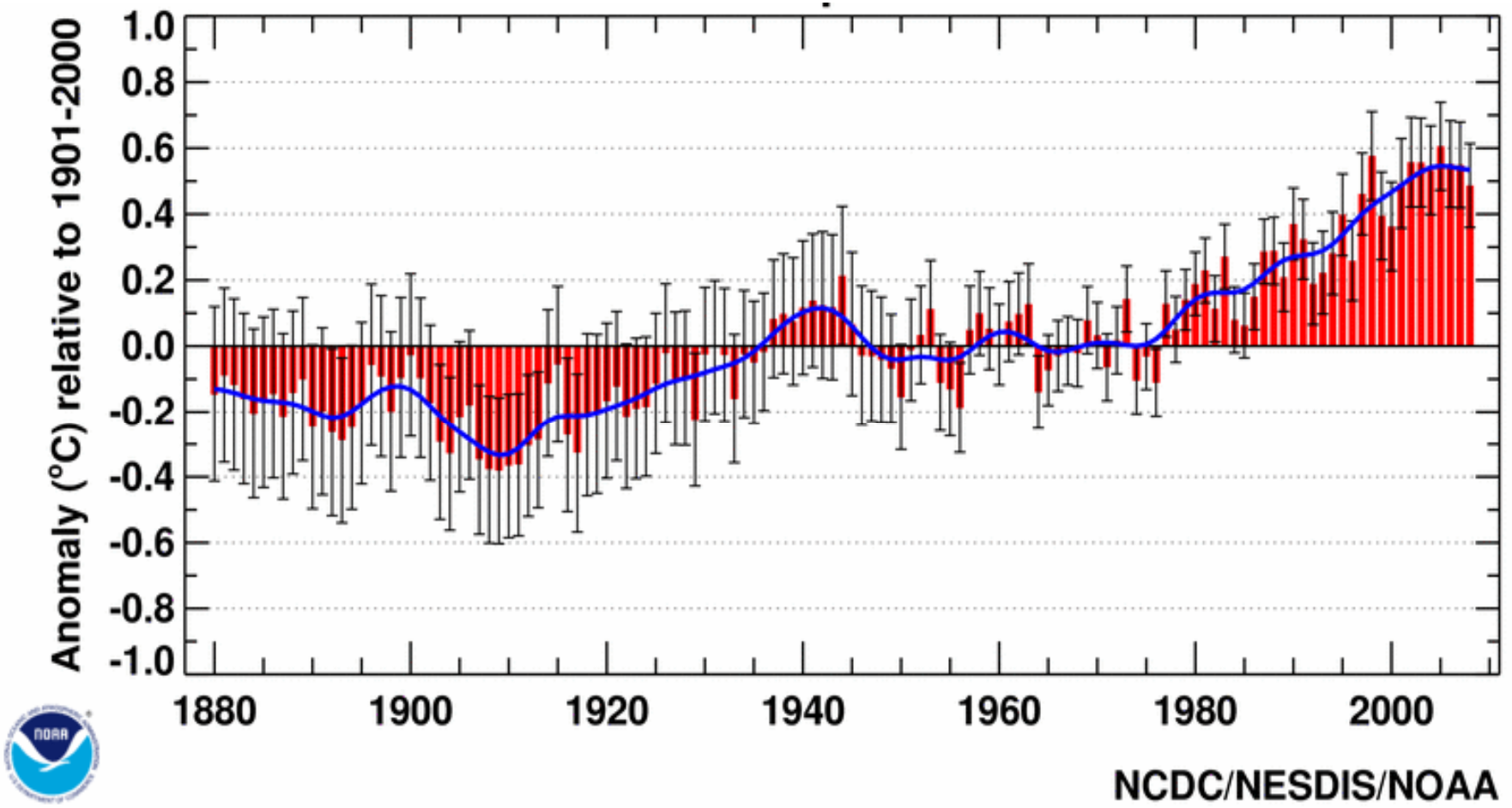
"We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard.

"Because that goal will serve to organize and measure the best of our energies and skills.

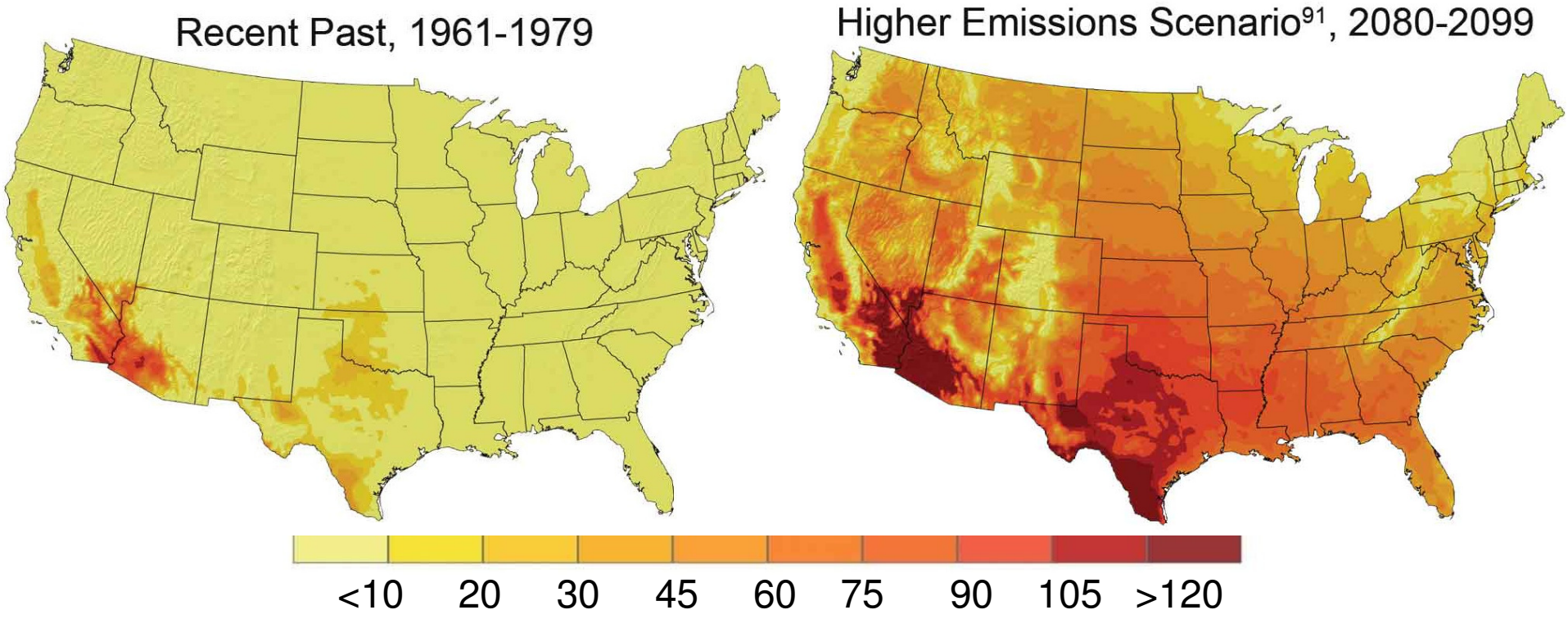
"Because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win…."

John F. Kennedy - September 12, 1962

Temperature Record (1880 – 2008)



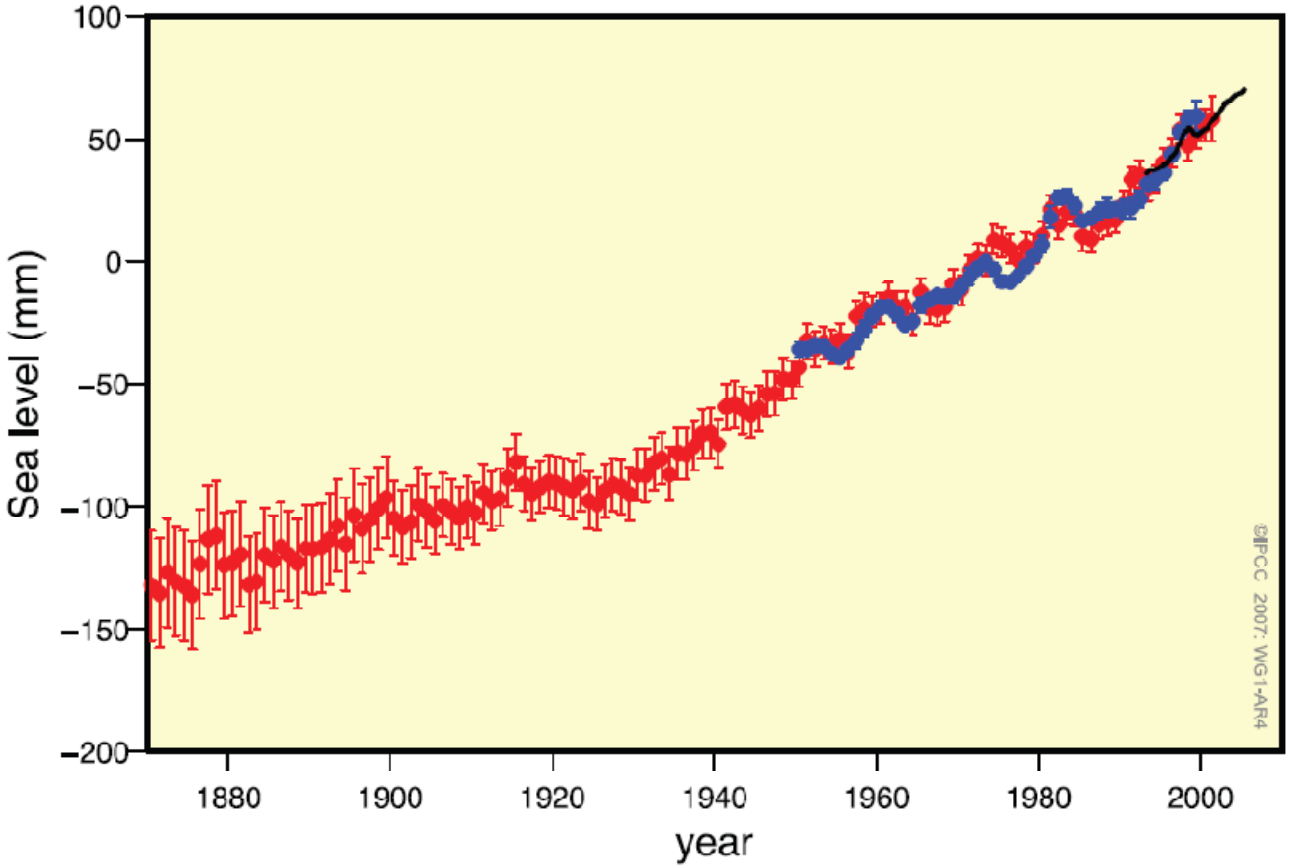
Days above 100º F



Much of the U.S. would go from 0 - 10 days above 100º F to 45 to 70 days per year above 100º F

Source: NOAA U.S. Global Change Research Program

Global Sea Level: 2007 IPCC Technical Summary



Past 2000 years: 0.0 - .02 mm/year

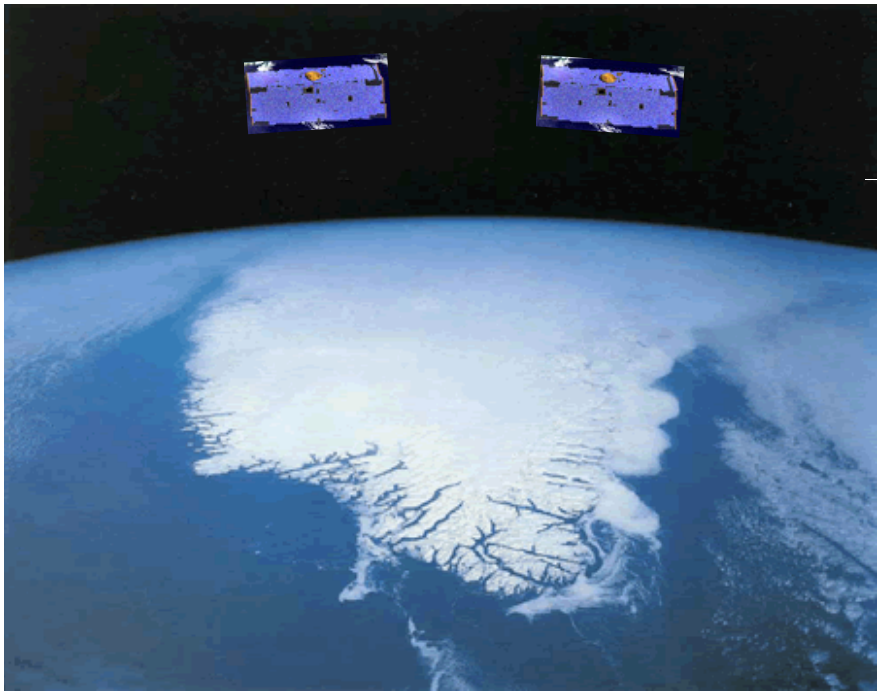
1870 – 1890: 0.6 mm/year

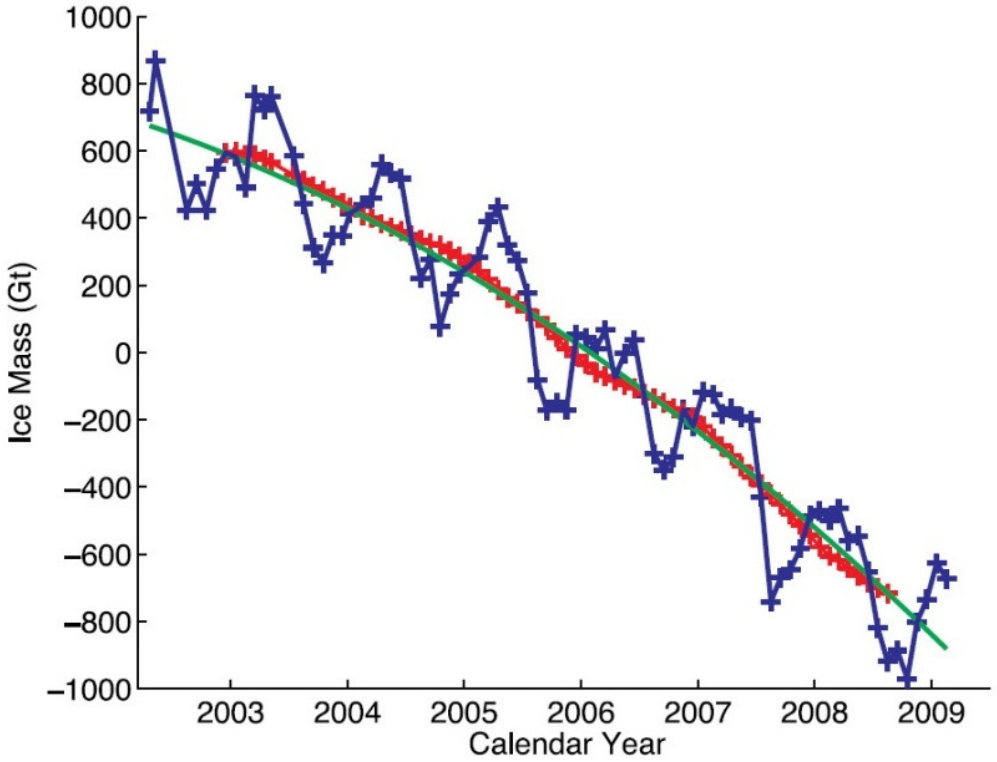
1990 – 2008: 3.0mm/year
(including recent satellite data)

The sea level is rising. Past 2000 years: 0.0 - .02 mm/year
Currently 3.0mm/year

Greenland Ice Mass Loss – 2002 to 2009

Ice mass loss from the Greenland and Antarctic ice sheets measured by **GRACE** (Gravity Recovery and Climate Experiment) mission.



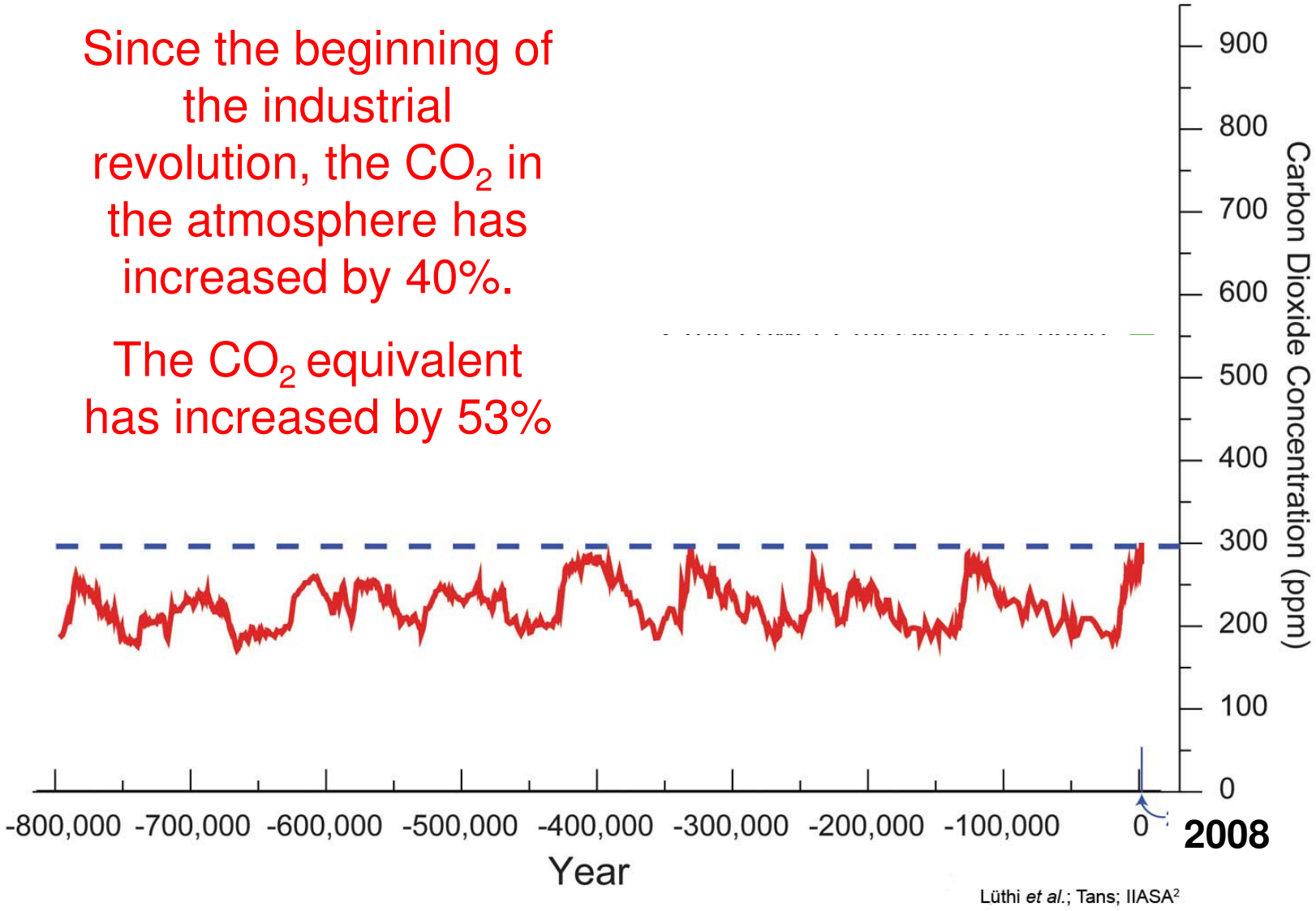


I. Velicogna, GEOPHYSICAL RESEARCH LETTERS, VOL. 36, L19503, doi:10.1029/2009GL040222, 2009

Carbon Dioxide Concentration during the past 800,000 years

Since the beginning of the industrial revolution, the CO_2 in the atmosphere has increased by 40%.

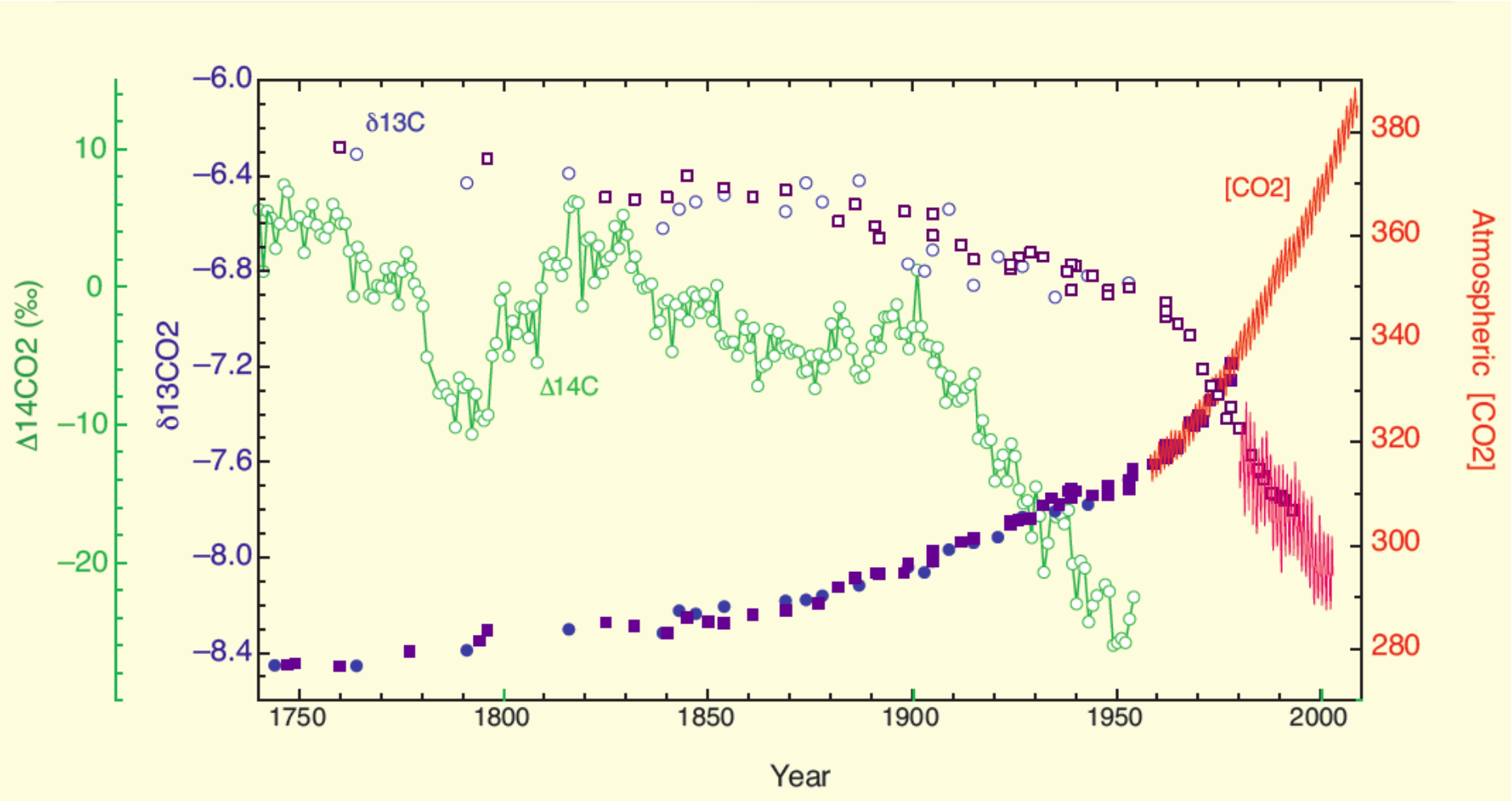
The CO_2 equivalent has increased by 53%



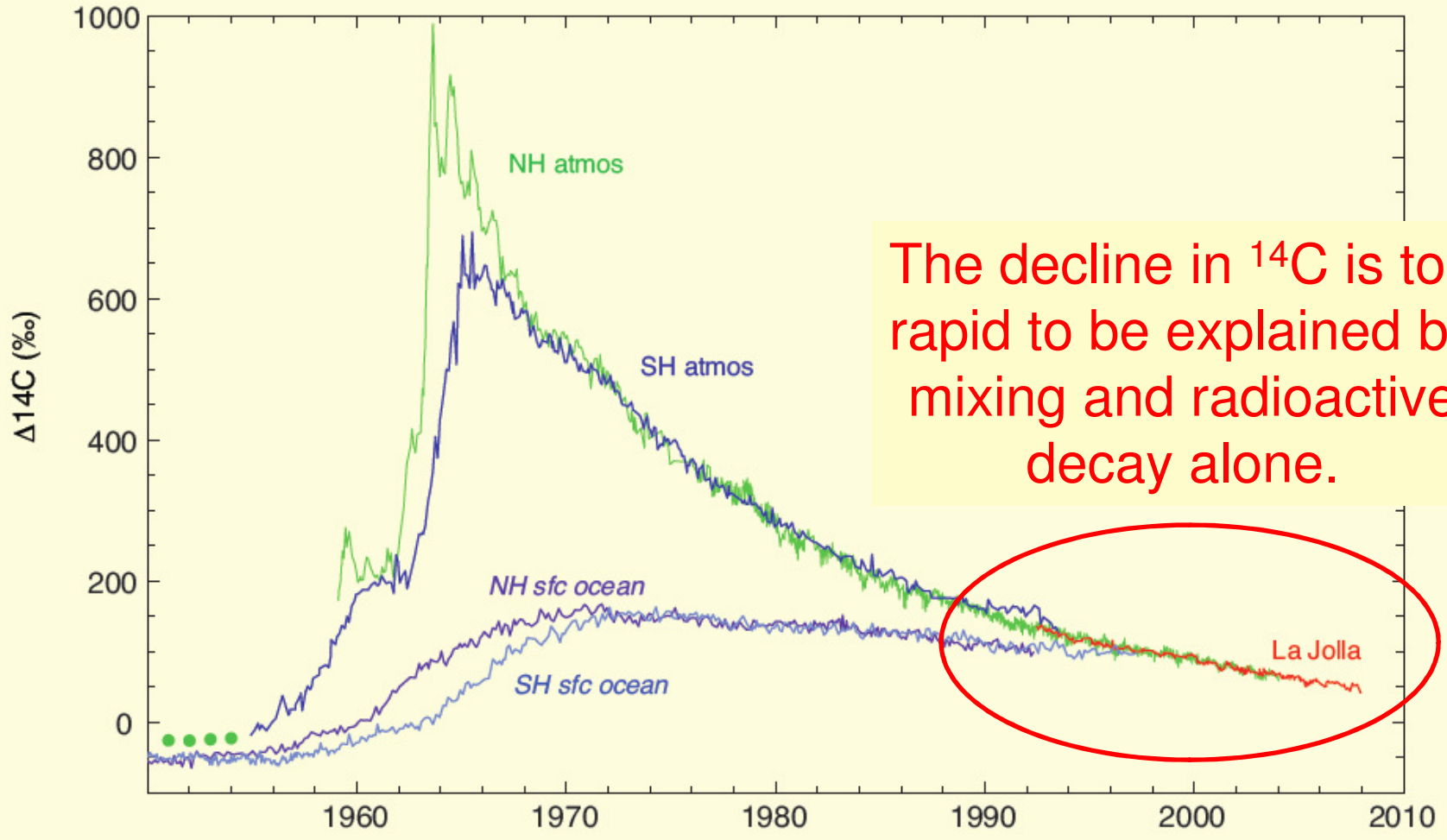
Lüthi *et al.*; Tans; IIASA[2]

^{14}C is produced through cosmic-ray bombardment. It is incorporated into plants and animals and decays with a 5,730 year half-life.

Fossilized organic material is depleted of ^{14}C. Burning fossil fuel will add ^{12}C to the atmosphere and lower the $^{14}C/^{12}C$ ratio.



Post 1950 Atmosphere and Surface Ocean $\Delta^{14}C$ History



The decline in ^{14}C is too rapid to be explained by mixing and radioactive decay alone.

Atmosphere

- Germany/Austria [Levin, assorted]
- Wellington NZ [Manning *et al.*,]
- La Jolla (CA) [Graven *et al., in prep*]
- NH annual [Stuiver and Quay, 1981]

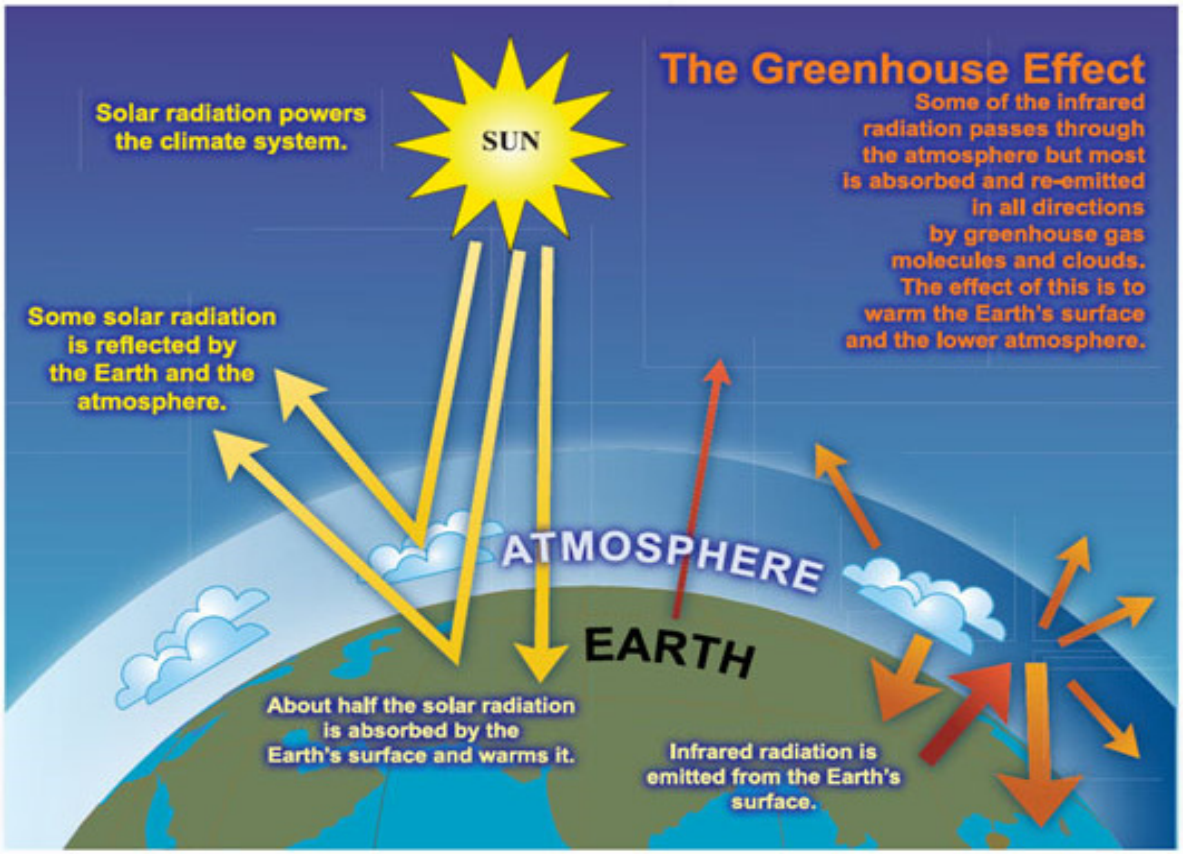
Subtropical Surface Ocean

- North Pacific gyre [Guilderson *et al., in prep*]
- South Pacific gyre [Guilderson *et al.*, 2000]

1) Solar energy hitting the Earth from the sun, averaging over the 11 year solar cycles, is constant. **(Input energy remains constant)**

2) Atmospheric greenhouse gases have increased. **(Less energy out)**

3) As the Earth begins to heat up, it is known that the change in temperature will be less than predicted by simple **Energy in – Energy out** analysis. The details of the geochemical and biological responses are not fully known.

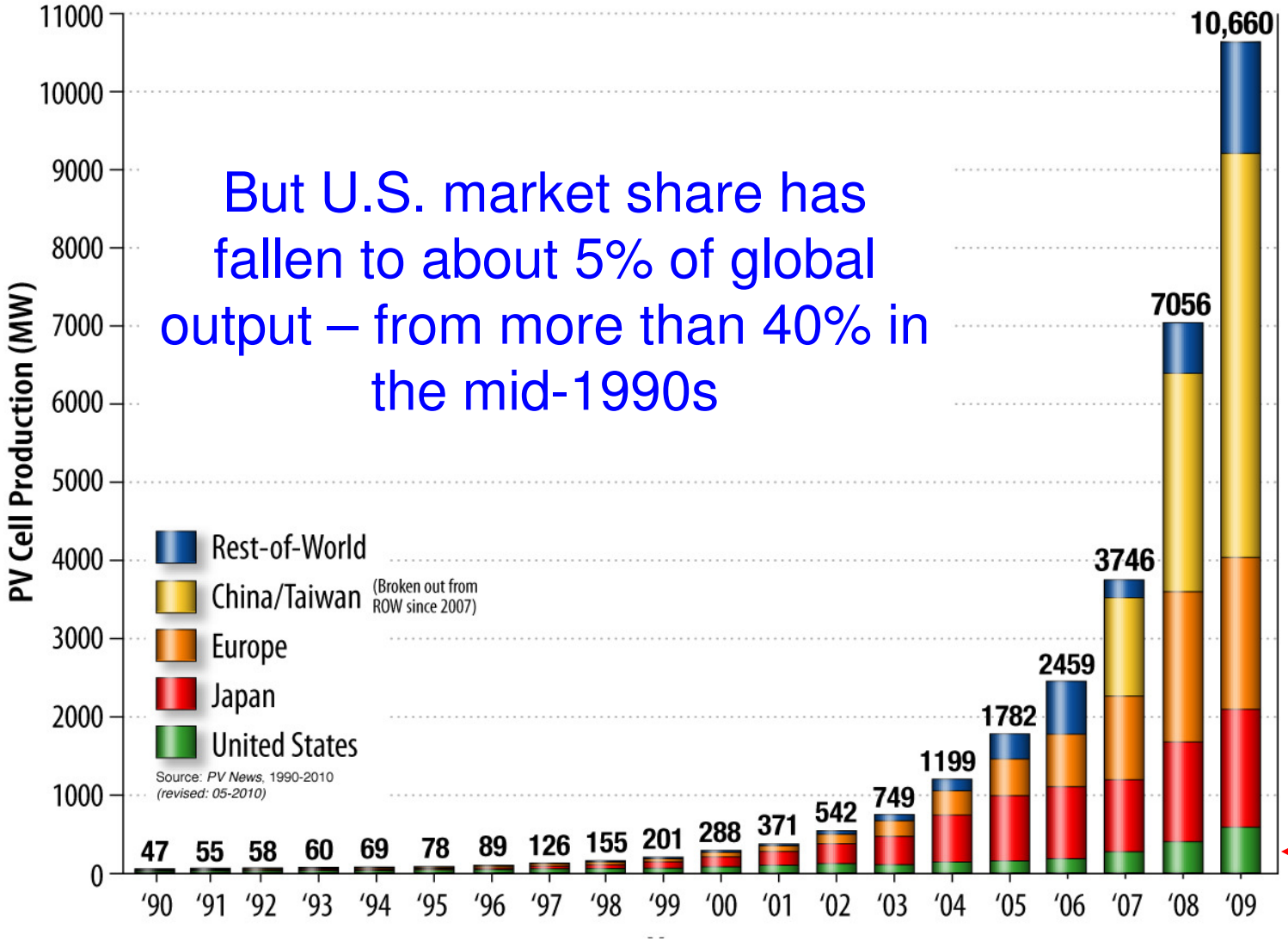


3) The Earth will warm up until a new equilibrium is reached:

When heat radiation out equals the absorbed solar energy.

(100 -200 years)

Solar PV is a booming global industry

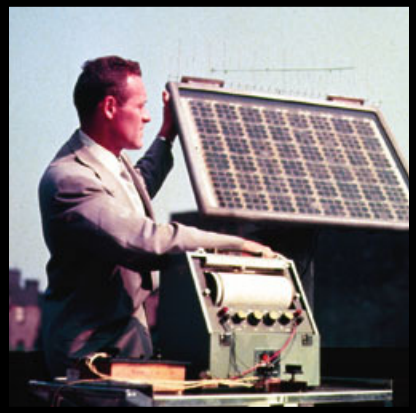


Worldwide production of solar photovoltaics – in Megawatts

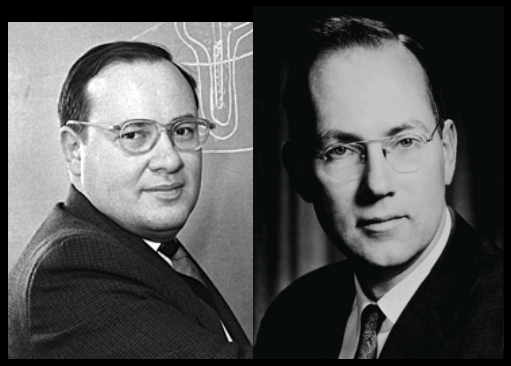
Bell Labs Murray Hill, New Jersey

17 Bell Labs scientists were awarded Nobel Prizes

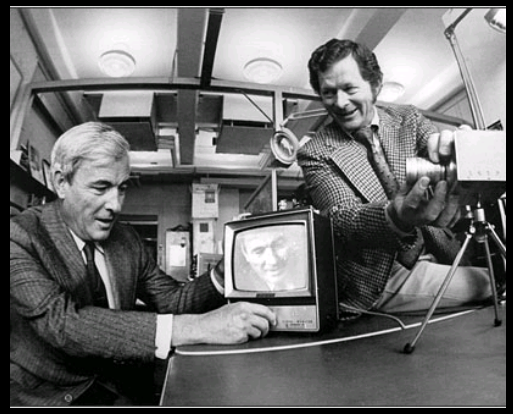
The Transistor



Silicon solar cell

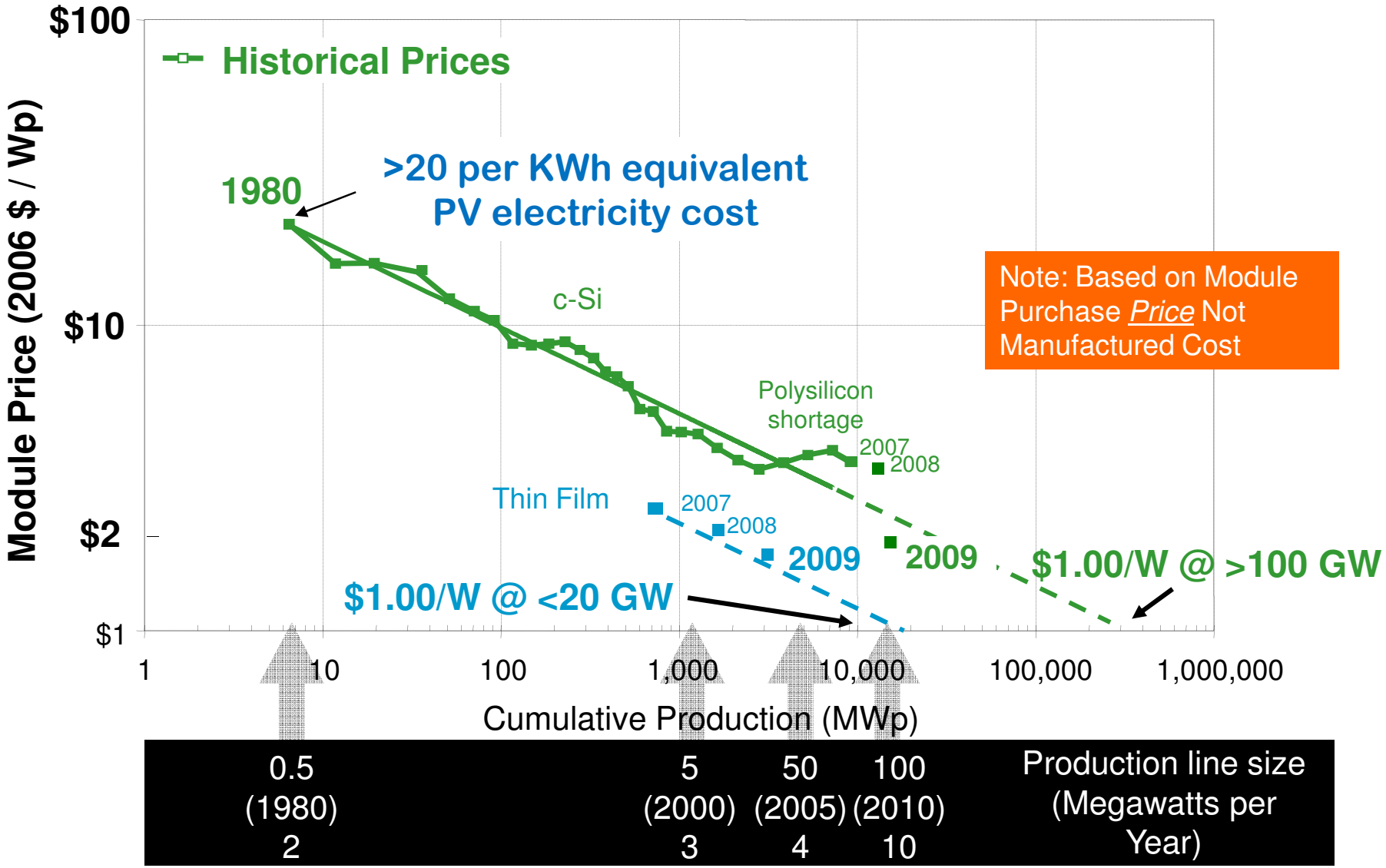


Schawlow-Townes Laser patent



CCD detector

PV module costs falling, but not enough to be cost-competitive



Source: Adapted from National Renewable Energy Laboratory

Where are we?

- Large-scale solar systems: $3 - $4 / watt,
  LCOE = 20¢ - 25¢ / kWh

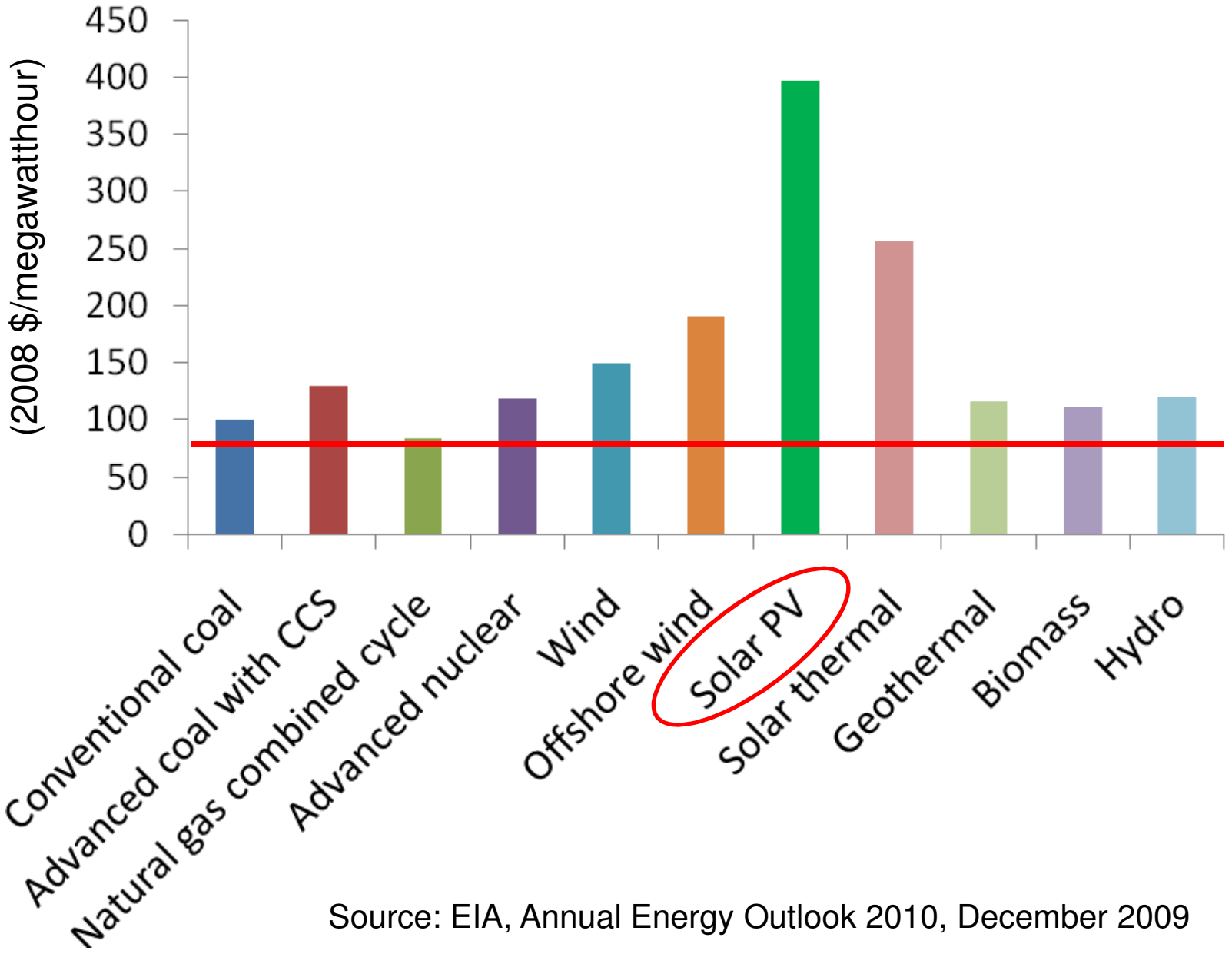
- Wholesale generation costs: 4¢ - 7¢ /kWh

- Retail rates: 8¢ - 14¢ /kWh.

- Over the past several years, solar prices have declined 40 – 50%

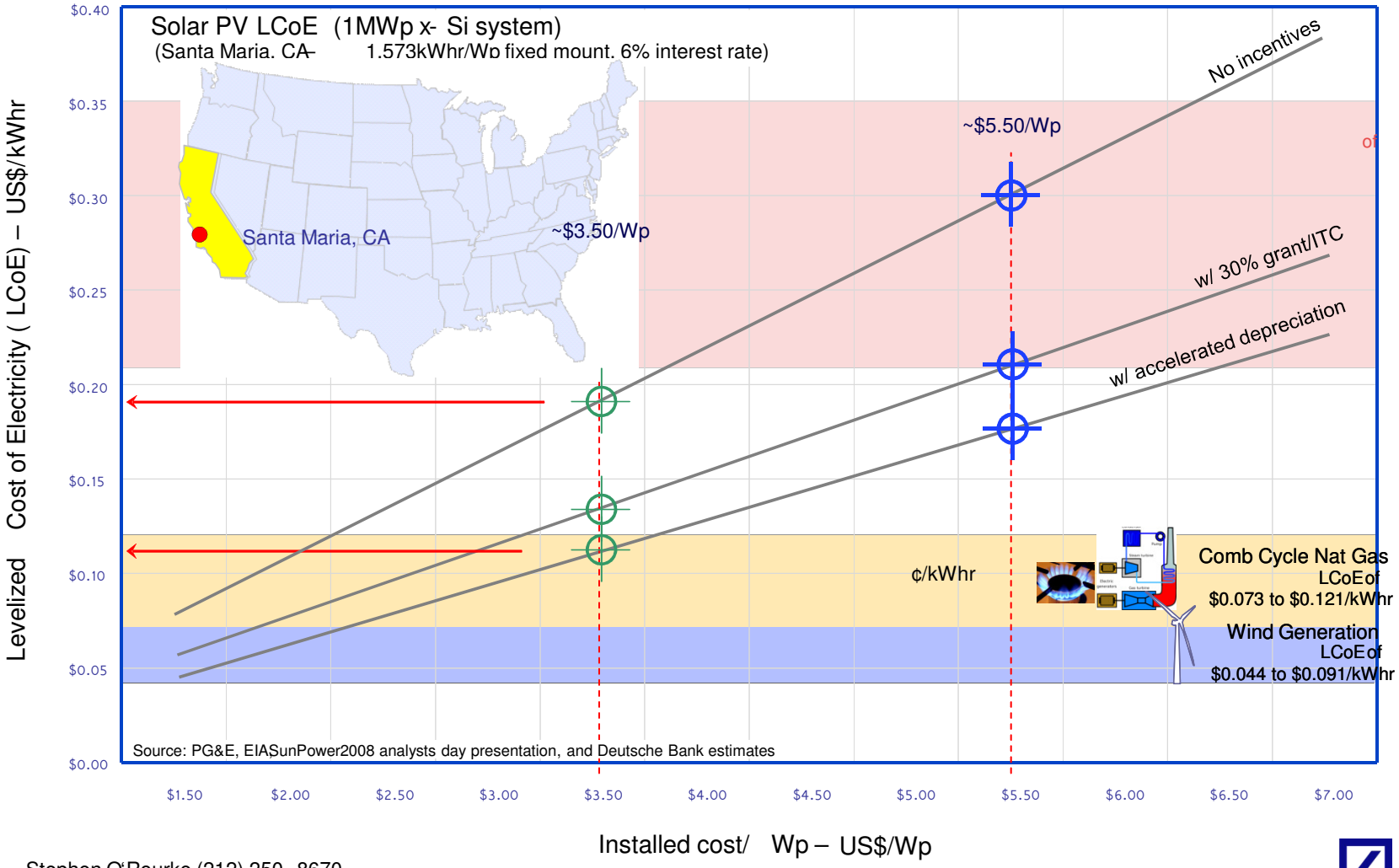
- Solar industry estimate: $2.20/watt (10¢ /kWh) in 5 years

EIA: Estimated Levelized Cost of New Generation Resources, 2016



Source: EIA, Annual Energy Outlook 2010, December 2009

Effect of $3.50/W TF + Utility Scale



Stephen O'Rourke (212) 250- 8670

Deutsche Bank

PV at $1/watt, installed:

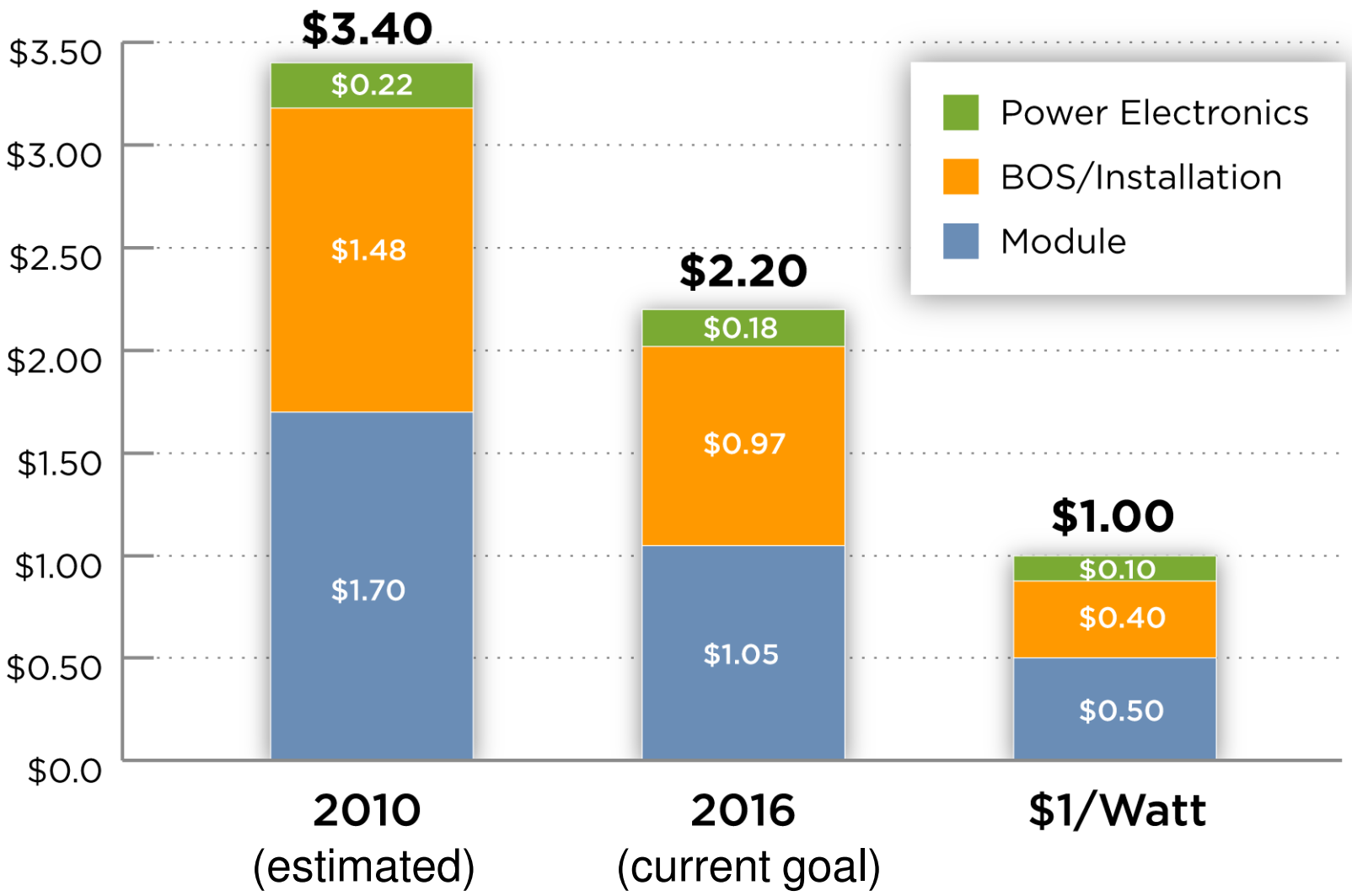
By 2017, demonstration of all key components and installation methods in systems at least 5MW in size and initial production orders made

Target could be met with systems installed on the ground or on buildings

Earth-abundant materials and recyclable components

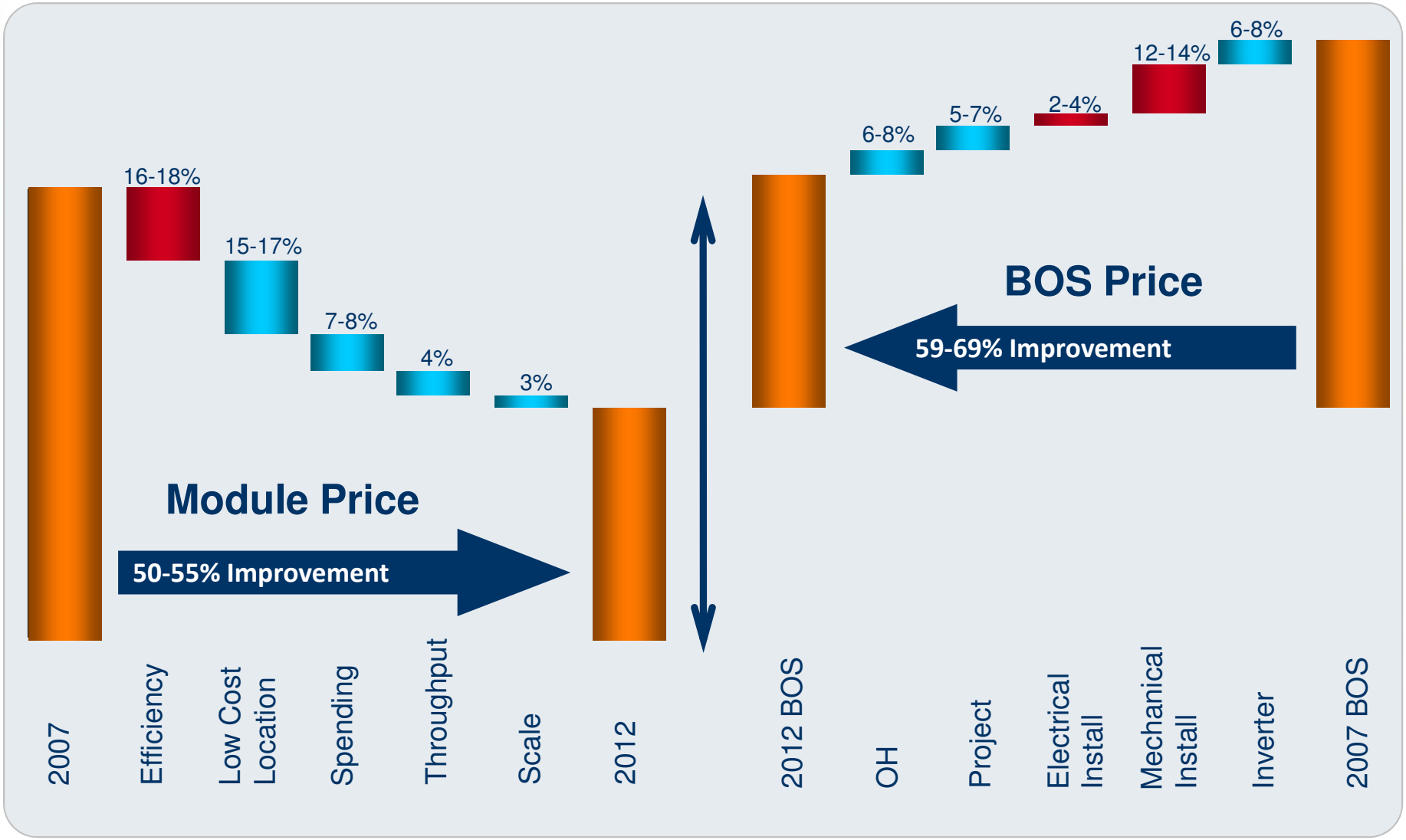
Meets all applicable safety and environmental standards

Reaching cost reduction targets will require advances in all PV system components



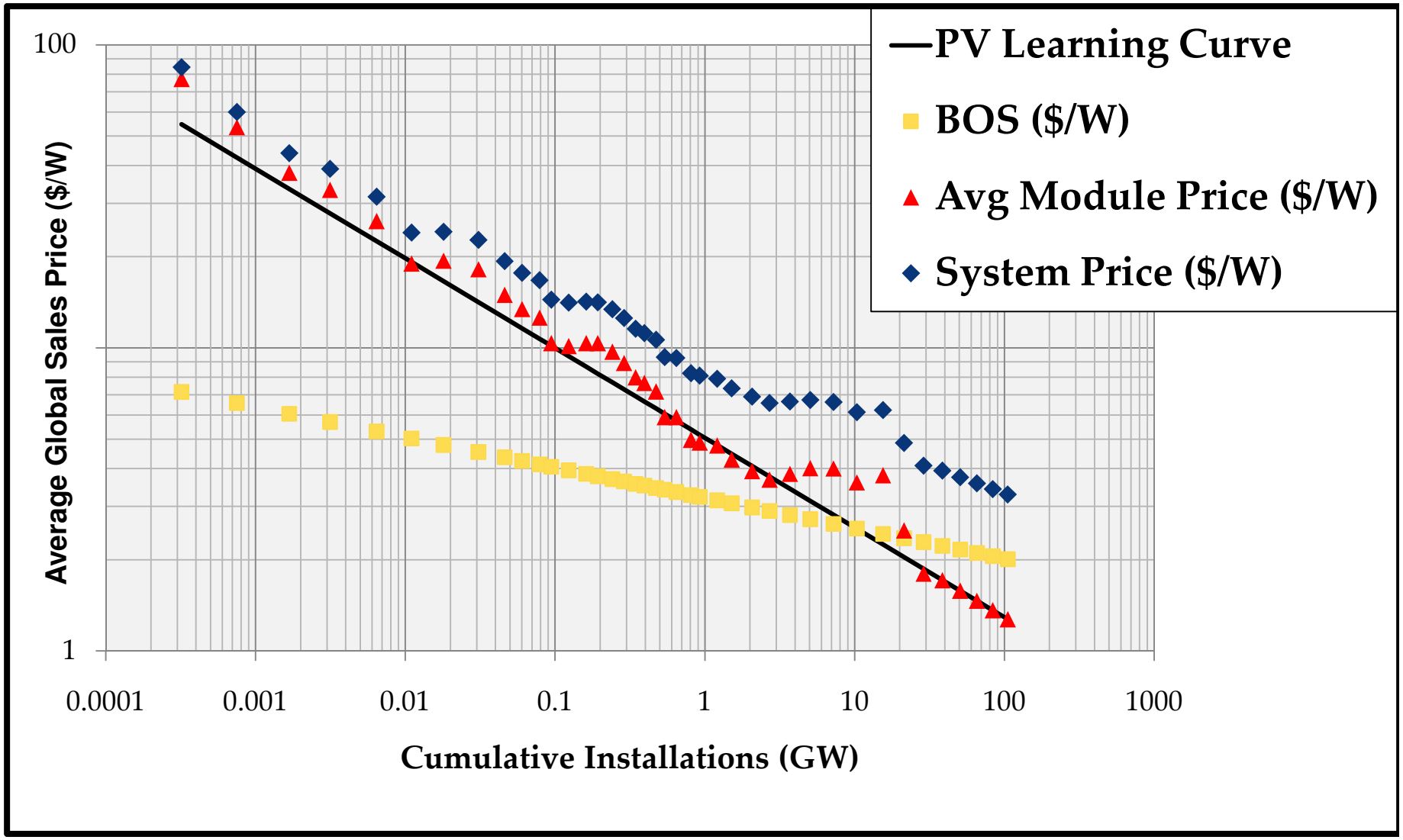
Utility System (Non Tracking) Cost Example

Scale Also Delivers BOS Cost Reductions (FSLR)



Source: Dave Eaglesham, First Solar & Mark Pinto, Applied Materials

Learning rates for PV systems will decrease as Balance of Systems costs begin to dominate total installation price.

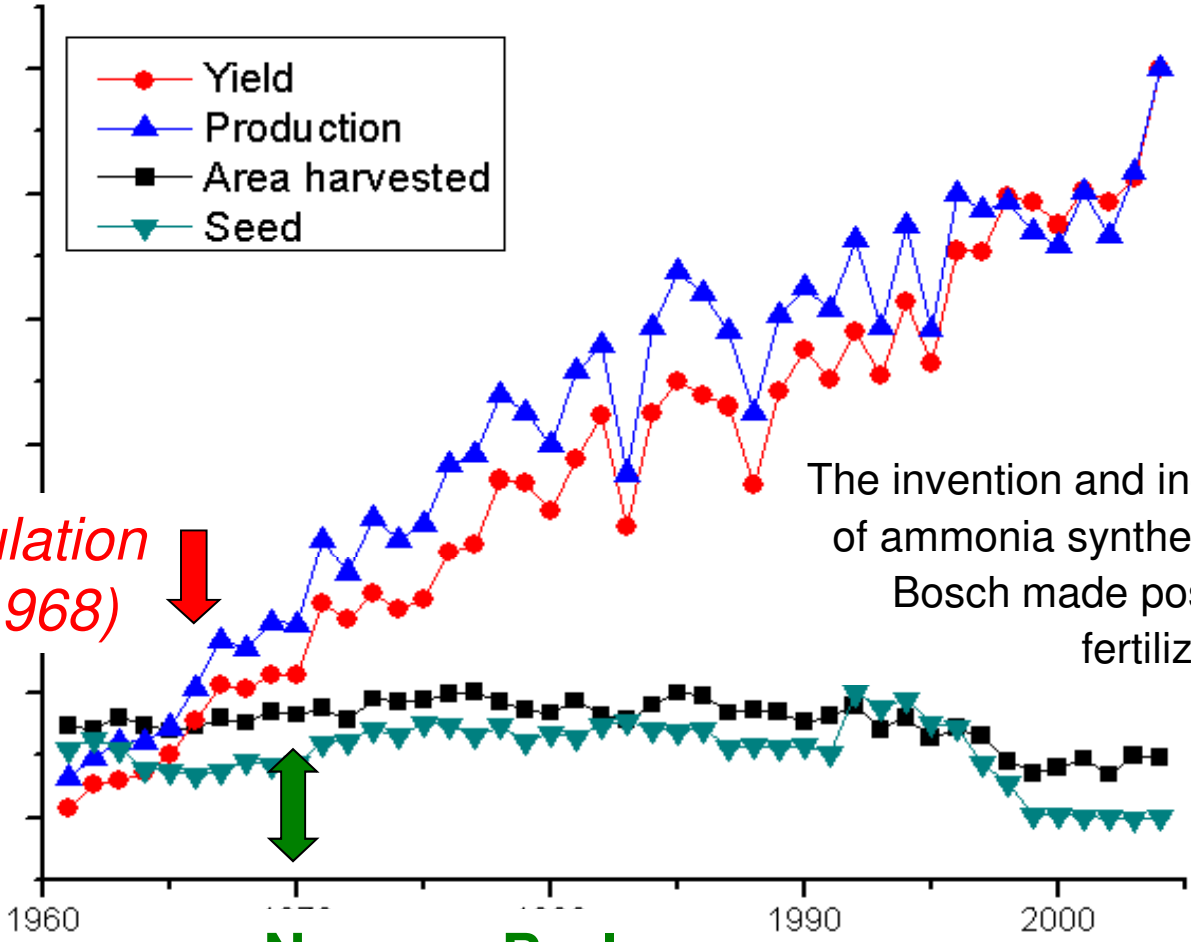


Source: Navigant Consulting

Science and Technology has given
us solutions in the past.

With the right government policies,
it will come to our aid in the future.

World Production of Grain (1961 – 2004)



The Population Bomb (1968)

The invention and industrial production of ammonia synthesis by Haber and Bosch made possible artificial fertilizers.

1960: Population = 3 B

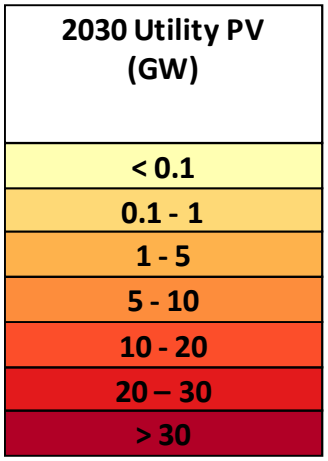
Norman Borlaug awarded Nobel Prize

2005: Population = 6.5 B

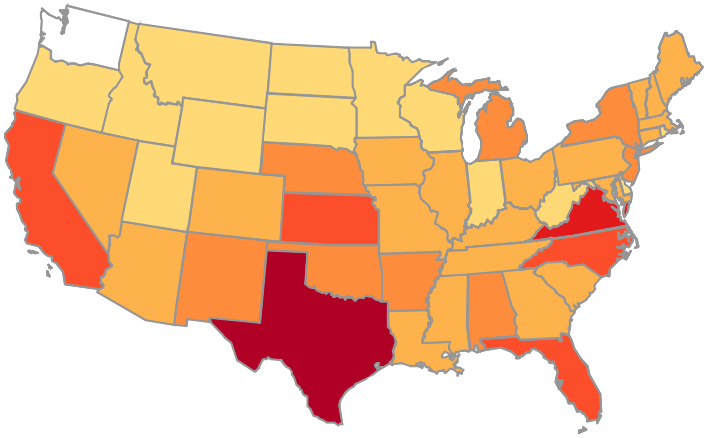
Source: Food and Agriculture Organization (FAO), United Nations

A $1/watt fully installed photovoltaic solar energy system – equivalent to 5-6 cents/kWh – would be a game-changer

Reference case



$1/watt case



NREL: At $1/watt, PV would be 14% of U.S. electricity by 2030, with minimal need for storage or additional transmission

We need a new mindset on cost-reduction.

Things we've never paid attention to before will be the difference between success and failure.

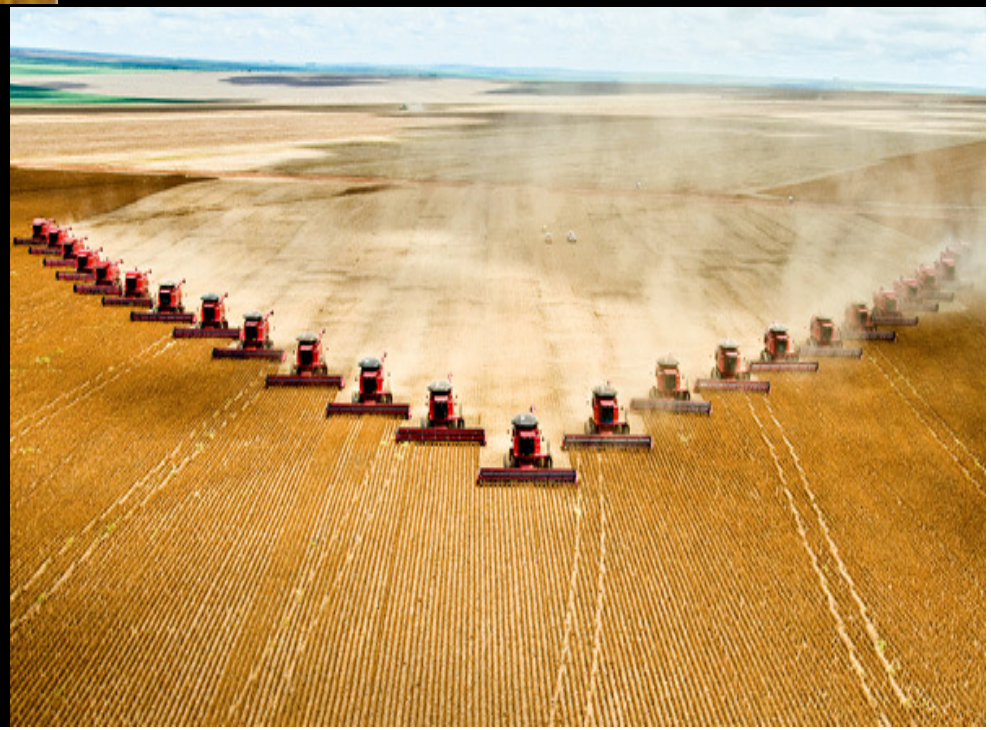
What can we learn from other industries?

Agriculture

From this…

…to this.

- Laser-leveled fields
- Fertilizer measured by satellite
- Harvested with GPS-enabled precision combines




Upgrading 6,500 dual pane windows in the Empire State Building
Innovative **on-site** processing – glass is removed, cleaned, retrofitted, and reinstalled without leaving the building

Containerized shipping has transformed global commerce

In 1959, the shipping industry loaded and unloaded 0.627 tons per man hour.

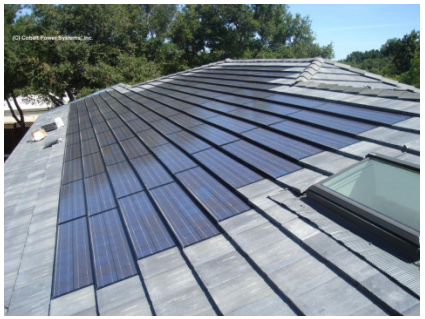
By 1976, the figure was 4,234 tons per man hour.

A ship's time in port shrank from three weeks to 18 hours.

Source: Matson Navigation Co.

- Minimize material use
- Lower weight, non roof-penetrating
- Micro-electronics integration
- Automated installation

Solar Shingles – or DIY solar – could nearly eliminate incremental PV installation costs



Earthrise from Apollo 8 (December 24, 1968)

"We came all this way to explore the moon and the most important thing is that we discovered the Earth.“

Bill Anders, Apollo 8 Astronaut

In 1990, Carl Sagan convinced NASA engineers to turn Voyager for one last, homeward look before leaving the solar system

"Look again at that dot. That's here. That's home. That's us. On it, everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives …. Every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, … every saint and sinner in the history of our species lived there--on a mote of dust suspended in a sunbeam."

"….The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate … Like it or not, for the moment the Earth is where we make our stand."

Deeply rooted in all cultures, is the notion of generational responsibility.

Parents want to give their children better economic opportunities

… and leave the world a better place.

- Science is predicting that we are altering the destiny of the of the Earth.

- The full impact of what we have done already will not be known for 100+ years. The full cost of future damages is not known.

- Are we willing to make investments that will protect our children and grandchildren?

An ancient Native American saying:

"Treat the earth well: it was not given to you by your parents, it was loaned to you by your children."

Our generation is in danger of breaking this sacred trust.